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Progress Report

on

TOOTH FLUOROMETER

by

Alphonse F. Forziati***
John W. Kumpula**
Joseph J. Barone*

*** Research Associate, American Dental Association Research Division, National Bureau of Standards.
** Laboratory Mechanic, Dental Research Section, National Bureau of Standards, Washington, D. C.
* Guest Worker, U. S. Army, Dental Research Section, National Bureau of Standards.

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

TOOTH FLUOROMETER*

Abstract

A fluorometer for the measurement of the fluorescence of teeth in the mouth has been designed and constructed. The fluorometer consists of a medium pressure mercury vapor lamp (as a source of ultraviolet radiation), a filter passing only U. V. radiation in the 3650 Å region of the spectrum, a lens for focusing the radiation onto the specimen, an annular lens to collect the emitted fluorescence, another filter (passing only visible radiation), and a photomultiplier radiation detector. The signal from the photomultiplier is fed into a direct current amplifier equipped with attenuation and sensitivity controls. The fluorometer has been used to record the fluorescence of natural teeth, artificial teeth and other materials.

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1. INTRODUCTION

For several years the Dental Research Section of the National Bureau of Standards has been interested in the fluorescence of human teeth when exposed to ultraviolet radiation. Studies [1, 2] on thin sections indicated that the organic constituents of teeth were primarily responsible for the fluorescence. It was also noted that carious areas [3] in tooth sections and some non-vital teeth did not fluoresce. Even the fluoride content of the water used by individuals seemed to affect the fluorescence intensity of their teeth [4]. These observations suggested that if the fluorescence intensities of the teeth, in the mouths of individuals whose histories were known, were measured under reasonably controlled conditions, valuable information could be obtained as to whether or not fluorescence measurements might serve as a diagnostic tool. Accordingly a tooth fluorometer has been designed and constructed.

2. CONSTRUCTION

The complete assembly is shown in Figure 1. The fluorometer(A) is suspended from adjustable arms (B) to facilitate positioning. The fluorescence intensity may be read from meters (C) and (C') or from the strip chart recorder (R).

2.1 Optical System

The optical system of the fluorometer is shown in Figure 2. Radiation from an AH4 mercury arc passes through a Corning 7-60 filter which transmits principally in the 365 mμ region of the spectrum. The ultraviolet radiation is focused by the objective to a narrow band, 1 x 3 mm, 6 cm beyond the small central lens. A disposable wooden applicator stick serves to locate this focal distance. A human tooth positioned at this point, absorbs the invisible ultraviolet radiation and emits visible radiation, that is, the tooth fluoresces in the visible region of the spectrum. The emitted fluorescence is collected by the annular lens surrounding the central lens tube.

After reflection by a diagonal mirror, the light passes through a filter* which transmits only in the visible, thereby blocking any ultraviolet radiation, reflected from the surface of the tooth. An adjustable iris diaphragm is used to regulate the amount of light reaching the photoelectric cell in the compartment behind the shutter.

* This filter was made by polymerizing hydroquinone-free methylmethacrylate containing 5%, by weight, of 2-hydroxy-4-methoxybenzophenone (Uvinul M-40) in a mold lined with very smooth tin foil.

A convenience light, mounted above the lens tube, is interconnected with the shutter so that the light is automatically cut off when the shutter is opened. This protects the very sensitive photomultiplier from exposure to light from this lamp. A mirror, also mounted above the lens tube, enables the patient to see his teeth fluoresce, thus increasing patient interest and cooperation.

2.2 Electrical System

A General Electric type 89G80 ballast transformer furnishes the voltage surge required to start the AH4 lamp and also limits the operating current to about 1.5 amperes. A miniature blower draws air in through holes in the base of the lamp housing, passes the air over the lamp bulb, and exhausts it through a light trap. Should the lamp housing overheat, due to failure of the blower or other causes, a bimettalic thermal strip opens the relay in series with the ballast transformer and shuts off the lamp. The blower circuit is equipped with an Amperite time delay switch which allows the blower to operate for about 90 seconds after the lamp is turned off. This removes the residual heat of the lamp components and prevents the distillation of the liquid mercury from the lower electrode compartment. Experience has shown that the lamp becomes difficult to start should this distillation occur.

The high voltage required by the 1P21 photomultiplier is furnished by a standard 1000 volt, stabilized power supply and the photomultiplier output is passed through a direct current amplifier equipped with zero, sensitivity, and attenuation controls, Figure 3. The amplified signal is fed to a series system consisting of a strip chart recorder and two microammeters, each with a sensitivity of 200 microamperes, full scale.

Normally, the recorder is shunted out of the circuit. By depressing a foot switch, the shunt is opened and the recorder is energized so that a trace is made on the chart. When the recorder pen has attained maximum excursion, the foot switch is again depressed, thereby shunting out the recorder. An Amperite time delay switch energizes the recorder chart drive motor for about 30 seconds, advancing the chart about 1/4 inch. In this way, a bar trace is made, at 1/4 in. intervals along the chart, every time the foot switch is depressed.

A full wave, selenium oxide rectifier supplies the low voltage, direct current required to operate the blower and the control relays. Figures 4 and 5 show the electrical connections of the auxiliary controls.

3. OPERATION

3.1 Calibration

Inasmuch as the fluorescence intensity indicated by the meters or recorder depends upon a variety of variables such as ultraviolet emission of the mercury arc, voltage of the power supply, ageing of the amplifier tubes, and sensitivity of the photomultiplier, some standard of fluorescence intensity must be used to calibrate the apparatus. Two standards, one of high fluorescence intensity and another of low intensity, were used in this study. A 2" x 2" piece of Corning glass C.S. 3-79, known as uranium yellow, served as a standard for average human teeth and a piece of Corning glass C.S. 0-54 was adopted as a reference for weakly fluorescent substances. To calibrate the instrument for the measurement of tooth fluorescence, glass standard 3-79 was placed in a special holder which aligned it at the proper focal point. After adjusting the amplifier so that its indicator registered zero, the attenuator selector was moved to the "x 100" point. The shutter was opened and the sensitivity knob turned until the meter read 90. The shutter was closed and the calibration procedure repeated at ten minute intervals until the meter reading did not vary by more than ±1 upon opening the shutter. The instrument was then considered sufficiently stable for use and the standard glass holder was replaced by a piece of ordinary wooden applicator stick, about 6 cm long.

3.2 Fluorescence Measurements

The patient was positioned with the head firmly against the headrest of a dental chair and asked to expose the upper (or lower) teeth as shown in Figure 1. Lip retractors were used if patients experienced difficulty in maintaining this position during measurement. The fluorometer was adjusted so that the wooden locator was perpendicular to and nearly touching the tooth surface. The optimum position was ascertained by observing the small microammeter mounted over the fluorometer lamp housing. By depressing the foot switch, the fluorescence intensity was recorded on the chart. When the operator pressed the foot switch once again, the recorder pen returned to zero, the chart advanced another 1/4 inch and stopped. The dentist adjusted the instrument on the next tooth and again made a record. The fluorescence intensities of the six upper anterior teeth were measured in this manner. Then the instrument was checked against the fluorescent glass. If the amplifier meter reading differed from 90 by more than ±3, the set of measurements was repeated; if it differed by less than ±3 but more than ±1, the measurements were corrected by prorating the change over the time span required to complete the set.

The fluorescence intensities of the six lower anterior teeth were also recorded. Results are given in Table I. These are preliminary data and no interpretations are intended.

The fluorescence intensity of any material may be measured by mounting it at the focal point of the fluorometer beam. Measurements on acrylic and porcelain teeth showed that they did not fluoresce as bright as natural teeth. Several brands of toothpastes packed in clear glass cylinders were also measured. Their relative fluorescence intensities are listed in Table II. These data suggest that the fluorescence method might be used to measure the time required for a given material to be cleared from the mouth and to locate areas of incomplete cleansing.

The instrument will be evaluated by measurements on patients of known histories, in cooperation with the National Institute for Dental Research.

REFERENCES

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2. Losee, F. L.; Jennings, W. H.; Lawson, M. E., Jr., and Forziati, A. F. Microstructure of the human tooth: a. the dentino-enamel junction. J. D. Res. 36:911 Dec. 1957.
3. Forziati, A. F.; Losee, F. L.; Pigman, W. W.; Jennings, W. H., and Lawson, M. E., Jr. In vitro production of experimental caries. J.A.D.A. 53:655 Dec. 1956.
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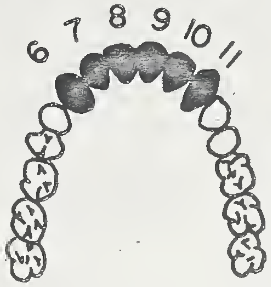
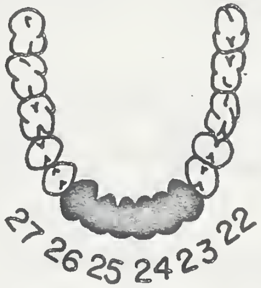
TABLE I

FLUORESCENCE OF HUMAN TEETH

PATIENT NO.	1 M	2 M	3 M	4 M	5 M				6 F
TOOTH NO.	INTENSITIES DIVIDED BY 100					AVG.	AVG. DEV.		
 6	63	51	76	57	41	58	10		—
7	54	40	55	52	36	47	8		4*
8	62	55	68	64	32	56	10		74
9	62	52	70	62	25	54	13		74
10	54	52	69	58	51	57	5		55
11	67	56	68	62	49	60	6		—
 22	69	89	100	78	45	76	15		—
23	81	86	100	85	69	84	7		63
24	94	69	80	90	42	75	16		76
25	+12	55	70	90	44	65	15		76
26	+12	60	70	86	31	62	16		70
27	85	85	90	71	56	77	11		—

*acrylic tooth +omitted from average

TABLE II

FLUORESCENCE OF TOOTH PASTES

BRAND	A	B	C	D	E	F	G	H	I	
FLUORESCENCE INTENSITY	50	24	19	50	250	50	45	62	18	

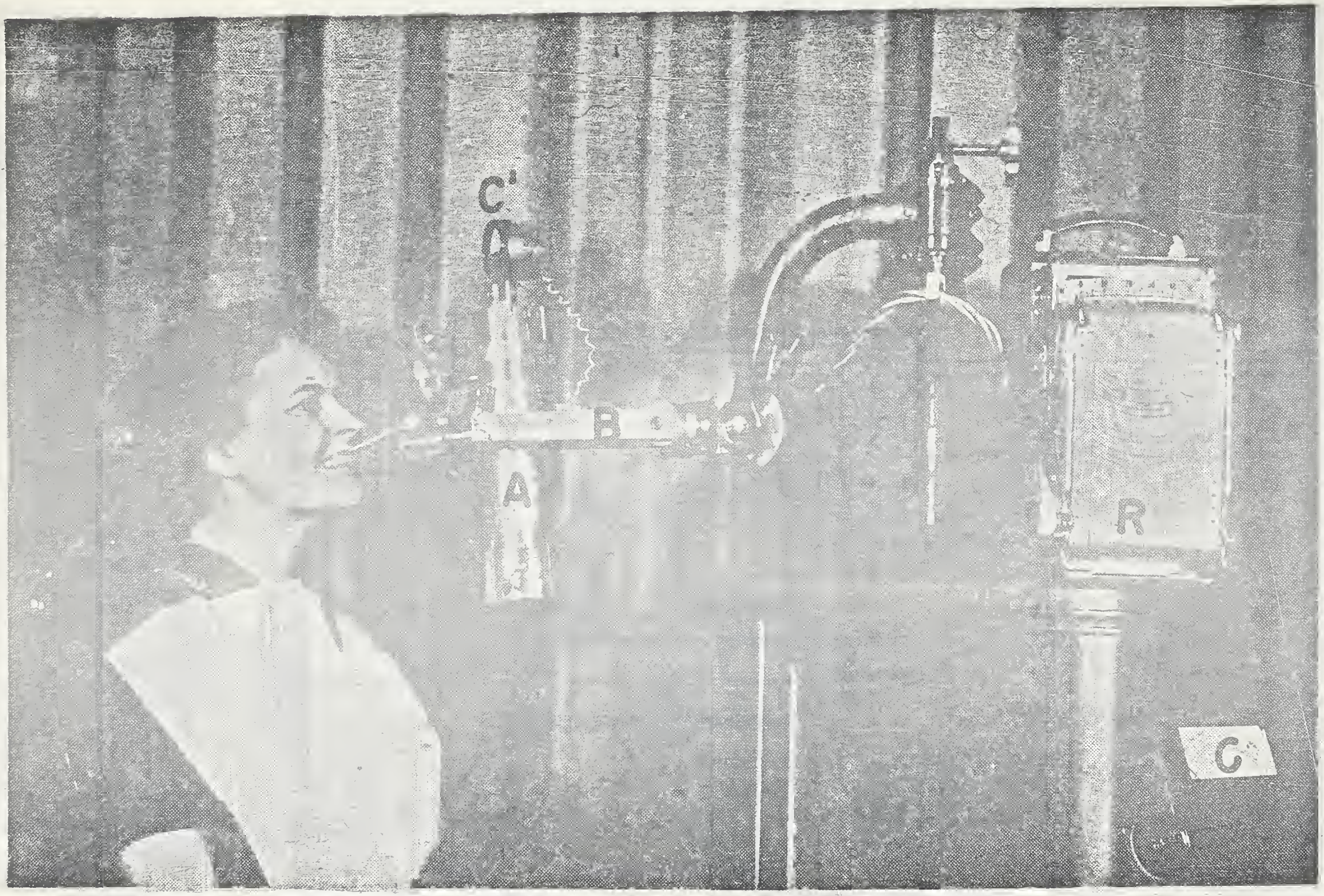


Figure 1. Tooth Fluorometer Assembly. A - fluorometer, B - adjustable arms, C and C' - fluorescence intensity meters, and R - strip chart recorder.

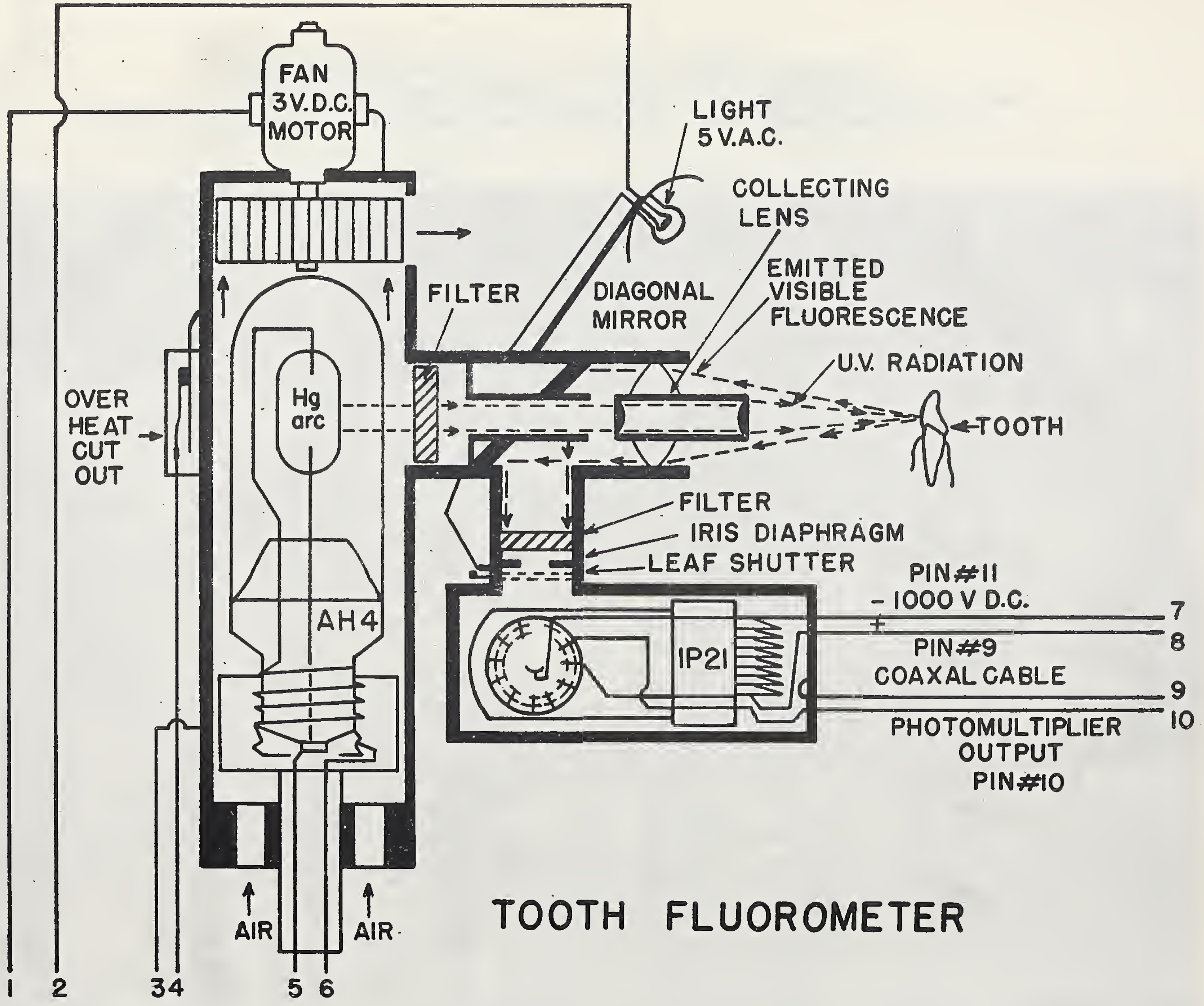


Figure 2. Optical System of Tooth Fluorometer.

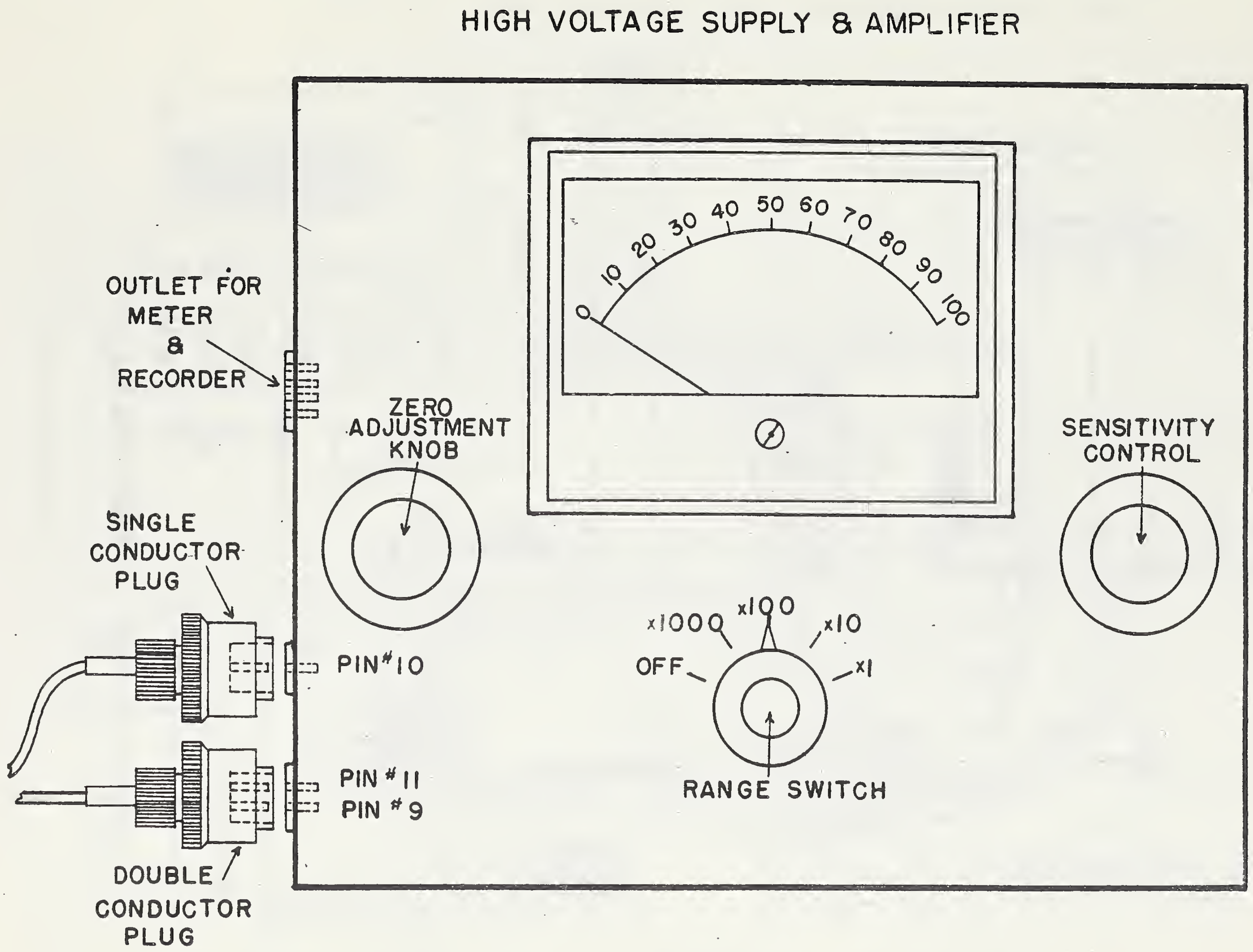


Figure 3. Power Supply and Signal Amplifier.

SCHEMATIC OF AUXILIARY CONTROLS

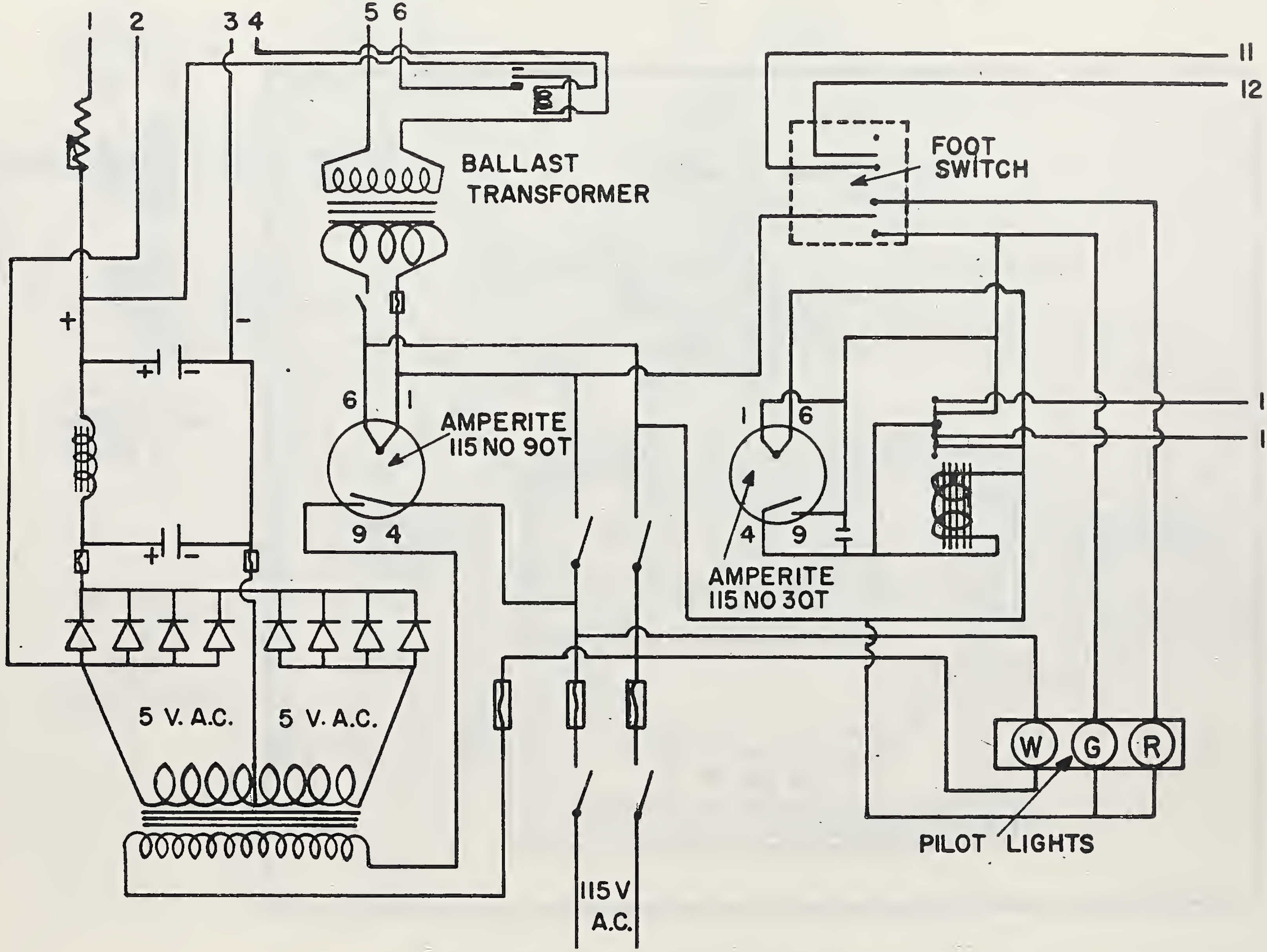
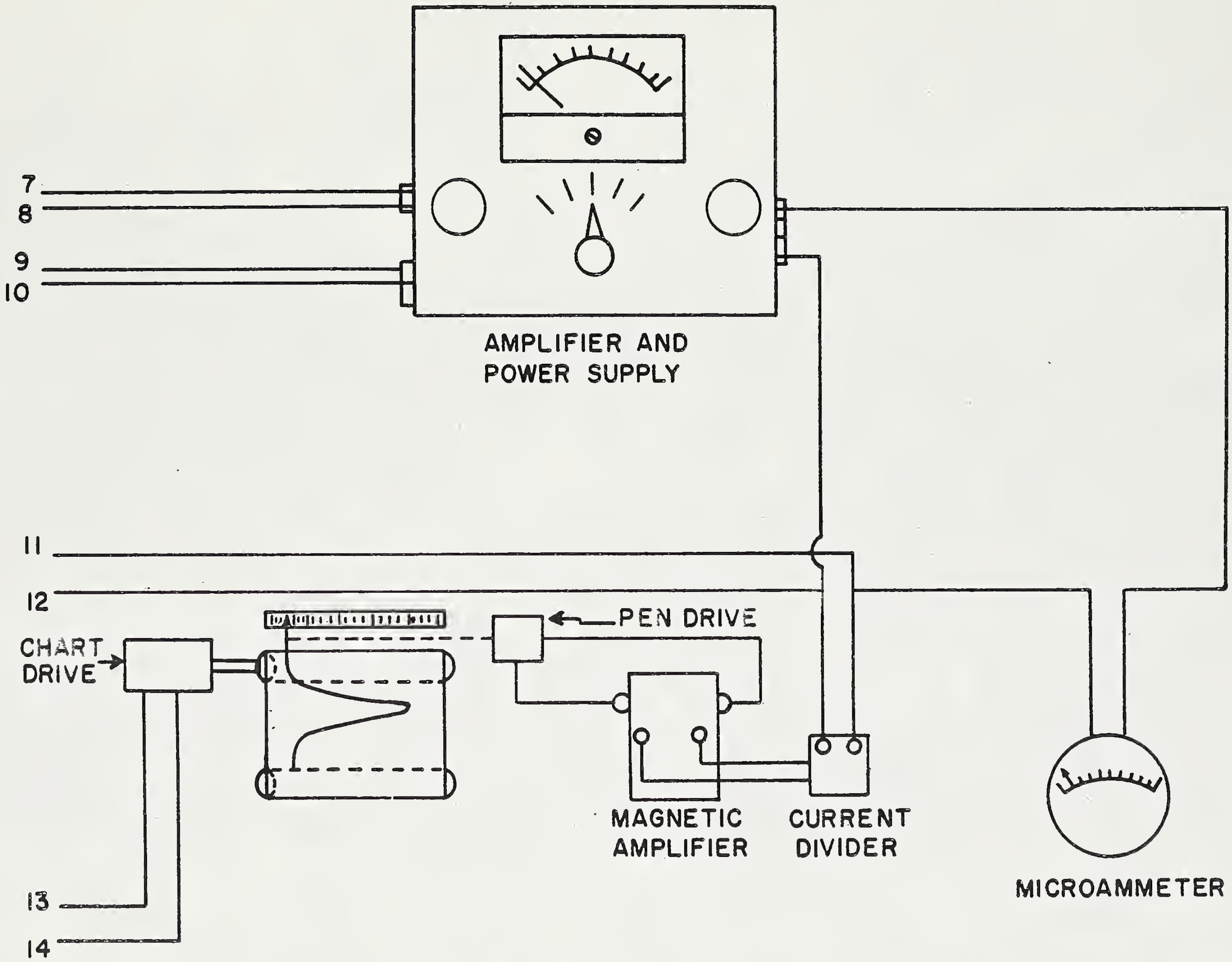


Figure 4. Low Voltage Rectifier and Relay Control System.



RECORDER AND MICROAMMETER ASSEMBLY

Figure 5. Recorder and Microammeter System.